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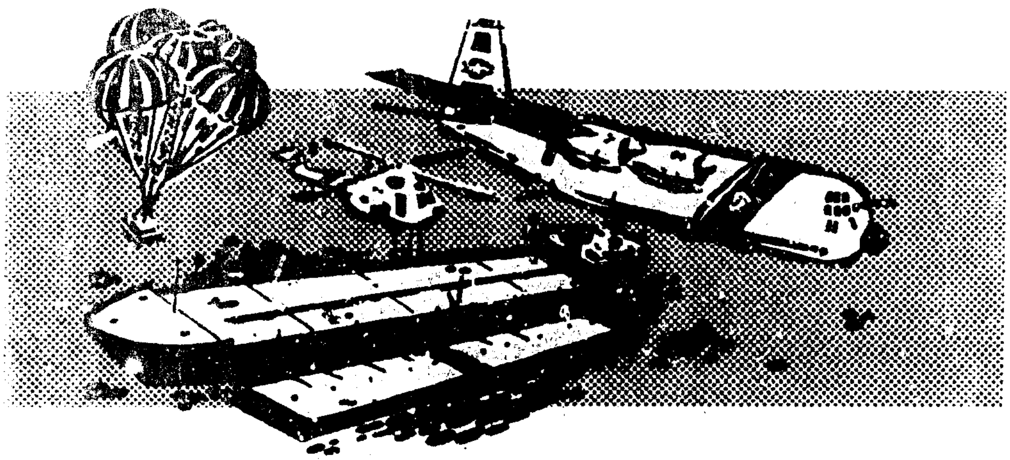
COAST GUARD

THE OPERATIONAL CAPABILITIES OF THE PROPOSED



Air Deliverable Anti-Pollution Transfer System

(ADAPTS)

VOLUME 1

Department of Transportation

United States Coast Guard

A Report on the Operational Capabilities of the Proposed Air Deliverable Anti-Pollution Transfer System

Volume 1: Study Method & Recommendations

Plans Staff

Office of Operations

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EXECUTIVE SUMMARY

This paper reports the modeling of the Air Deliverable Anti-Pollution Transfer System (ADAPTS) to determine the optimal mix of resources needed for the use of ADAPTS and to measure the capability of ADAPTS. Modeling was accomplished using at first PERT/CPM diagram methods and later using a simulation model. The results of the first method were used to validate the simulation. Then a mathematical model was developed for use on the Coast Guard computer. While the mathematical model is limited in the number of situations it can investigate, it is accurate and more rapid.

When sufficient modeling results were obtained, they were evaluated with the budgetary and aircraft limitations on the system and recommendations for alternate equipment and procurement of ADAPTS were developed. The general result of the study is that the turn around time of the C-130 aircraft must be minimized and that there must be sufficient ADAPTS pumps on scene early in the deployment of the system.

Improvement in the turn around time of the C-130's is costly but the benefits are necessary. The cost increase does not detract from the value of ADAPTS since the clean-up cost of an average incident is higher than the initial cost of ADAPTS. The procurement of cargo rails which can be installed rapidly on the C-130's is necessary and compatible airplane loaders are needed.

Early deployment of ADAPTS pumps can be accomplished by use of pre-positioned pump and prime mover packages that are scaled for helicopter delivery from advance bases such as the network of Coast Guard air stations.

Better utilization of pumps at the scene of the incident can be had by furnishing Y-gates or manifolds so that switching from a filled bag to an empty one can be accomplished without delay. This would increase the maximum possible utilization of pumps on scene from 0.8 to 1.0.

A specific requirement for eight complete air crews to fly C-130's out of Elizabeth City exists for ADAPTS. The system can be effective with five C-130's and eight crews; with less, it will only ameliorate the size of the resulting spill.

INTRODUCTION

In March of 1967, the supertanker TORREY CANYON went aground while approaching the British Isles. A small ship could have navigated the passage but the immense tanker was unable to pass through it. The ship was stranded; efforts to free it failed and efforts to lighten it were unsuccessful since there was no way of pumping large quantities of crude oil from the tanker and there was no way to bring other tankers close to the TORREY CANYON without the risk they would go aground as they were filled.

The TORREY CANYON remained aground for a week before a storm destroyed it. It lost its cargo of oil during that week; slowly at first from bottom damage, then faster during the salvage attempts after an explosion occured. When the impossibility of saving the tanker and oil was painfully clear, the Royal Air Force was ordered to destroy the stranded tanker with incendiary bombs. The fires that resulted fizzled and the crude oil, instead of burning as desired, poured into the sea through the bomb damage. At the end of that week an Atlantic storm broke up the hull of the TORREY CANYON and the rest of the cargo was released. Approximately 120,000 tons of oil (30 million U. S. gallons) were lost.

The world took notice of the grounding. It was called catastrophic. It was unique. Many governments felt that it should never occur again[1]; others, feeling that it will happen again, studied the British reports and began preparing.

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[1] A spill this large has not occurred since, but since then over five supertankers have exploded and sunk. The [illegible] for disaster is very high.

A system of men and equipment is being developed by the U. S. Coast Guard to meet this specific problem. This paper reports the results of a study of the operational use of the system.

The Coast Guard is the agency of the United States Government that is responsible for control of oil pollution along the coasts and contiguous seas. It was assigned this responsibility since it regulates maritime industry, enforces federal law on the seas, and has a large organization for rescue of persons and ships on the high seas and the coasts[1].

The United States has never suffered a TORREY CANYON size oil spill; however, it has suffered at least one spill of 10,000 tons (2.5 million U. S. gallons) each year since. The spills have become more frequent and larger during the past decade[2]. These increases have paralleled increases in tanker size, number of tankers, amounts of oil shipped, and world consumption of oil.

Time is very important, the efforts to prevent spills when a tanker goes aground and to retrieve spilled oil are reactive processes; that is nothing can be done until it must be done, and when an effort is made, it must be made during favorable weather. On the eastern coast of the United States for example, weather follows a cycle of five days good weather followed by a one or two day storm. Because of this time constraint the system has been designed to be delivered by aircraft from a central depot to the location of the distressed tanker. For the same reason the measure

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[1] The George Washington University. Legal, Economic and Technical Aspects of Liability and Financial Responsibility as Related to Oil Pollution. Contract [illegible]. December 1970.

[2] Ibid.

of effectiveness[1] for the system as modeled is the amount of oil that can be removed from the tanker in 24 hours.

A brief summary is in order. To prevent oil from being spilled from a stranded (or otherwise distressed) tanker during the short time available between the beginning of the distress and the release of the oil cargo into the sea, a system of aircraft deliverable equipment and people is being developed by the U. S. Coast Guard. The system is named the Air Deliverable Anti-Pollution Transfer System and the acronym used is ADAPTS. The effectiveness of the system is measured by the amount of oil it can transfer from the tanker in 24 hours.

[1] Cost will not be used as a measure [illegible] ectiveness in the models since these models are for operational [illegible] ubject to a given set of resources: the equipment and men of the system. Cost effectiveness considerations are used in evaluating the results obtained from the models to develop the recommendations in the following chapters.

CHAPTER 1

DESCRIPTION OF THE SYSTEM

The Coast Guard, as part of a continuing program for prevention and control of oil polluting the sea, has contracted for development of a prototype system for the emergency unloading of oil cargoes from stricken tankers (dubbed ADAPTS: for Air Deliverable Anti-Pollution Transfer System). ADAPTS is a parachute-dropped system utilizing diesel-hydraulic submersible pumps to transfer oil to large, seaworthy rubberized nylon containers (often called tanks or bags, these will be called bags hereafter).

The prototype ADAPTS was developed by Ocean Science and Engineering, Inc. under Coast Guard Contract DOT-CG-92,087-A. Further development and testing of the pumping equipment is presently in progress at Coast Guard and other government testing facilities. Similarly, additional development and testing of the bags are being accomplished under parallel contracts with UniRoyal, Inc. (DOT-CG-11,299-A) and Goodyear Tire and Rubber Company (DOT-CG-03,083-A).

The system design and performance data resulting from these development and testing projects was used for the study reported herein. Slight design modifications or improvements may be needed for the system, based on the results of final prototype tests. For this reason the results of this study may apply only in general to the final system although they apply fully to the current design of the system.

ADAPTS is designed for air delivery using Coast Guard HC-130B Aircraft and for on-scene deployment at any location within about 100 miles of the coast by Coast Guard HH-3F or HH-52A helicopters. Initially, support from surface craft is unnecessary. A specially-trained Coast Guard crew is delivered to the scene by helicopter to operate the equipment. ADAPTS is designed for delivery and operation in winds up to 46 mph with 8-12 foot seas.

Although the system is designed for helicopter deployment for high-seas applications, it can be deployed just as effectively although far slower by vessels. This method is particularly applicable to in-port and near-shore utilization.

For the purposes of this description, ADAPTS can be divided into four parts:

a. the C-130 equipment air station for heavy lift and long-range delivery.

b. the helicopter's (and their support) for personnel and equipment delivery and early work at the scene.

c. the ADAPTS equipment and bags used at the scene, and

d. the salvage teams and their life support equipment.

The C-130 Aircraft

The HC-130 aircraft used by the Coast Guard are described herein since they are the most numerous and least capable of the C-130's in the Coast Guard inventory; any task that can be handled by an HC-130 can be handled by the others. This C-130 can carry 17,000 pounds of cargo with 40,000 pounds of fuel at an average speed of 270 knots air speed from an air station (270 knots is CG practice; 2[illegible] knots is generally used in returning). The average fuel consumption is 4000 pounds per hour. The maximum weight of cargo that can be carried and air dropped is 25,000 pounds with approximately 37,[illegible] pounds of fuel at takeoff. Since this will vary with the weather and the shape and weight location of the cargo, this capacity should be used for planning purposes only and not for operation of the aircraft. These figures serve for rule-of-thumb planning; they indicate that a C-130, loaded with 25,000 pounds of air dropped cargo can travel 1[illegible]0 miles in four hours, forty minutes, drop the cargo and return to its base with one hour of reserve flight time.

The CG fleet of C-130's is located at the following air stations:

Air Station	Number of C-130's
Elizabeth City, N. Carolina	5 (another one is electronically configured and not available)
San Francisco, California	2
Kodiak, Alaska	5
Barbers Point, Hawaii	3

An additional [illegible] has been budgeted for [illegible].

Each C-130 has four pilots and twenty one crewmen allotted to make up an aircrew of three pilots plus six crewmen. The scheduling standard for an aircrew is 8 hours flight time a total mission time of 12 hours.[1] Annual and initial costs[2] are:

Item	Annual Cost	Initial Cost
C-130	$424,300	$3,550,000
pilot	19,975	21,200
crewman	8,495	330

Two factors which seriously affect the ability to deliver the ADAPTS equipment in a timely fashion by C-130 are the number of C-130's available and the means of loading them.

Due to scheduled maintenance and other factors, the C-130's operated by the Coast Guard are not available for work 25% of the time.[3] Since the non-availability generally is planned, the periods of non-availability are staggered to enhance the number of aircraft available at any time. We will assume that such staggering is not done; hence, the non-availability for work of each C-130 is independent of the other aircraft. This assumption will result in a lower availability (in this sense it is conservative) than actual practice allows but it will allow the use of a binomial probability distribution to described the number of C-130's available.

For Elizabeth City Air Station (5 C-130's) we have:

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[1]Paragraph 202.2.1 of the Air Operations Manual, CG-333.

[2]COMDTNOTE 7100 dtd 25 Feb 71 and current budget submissions.

[3]Planning factor used by COMDT (OS[illegible]) based upon experience with all types of CG Aircraft.

Number Available	Percent Time
5	24
4	40
3	26
2	9
1	1
0	0.1

This means three or more C-130's can be expected 90% of the time. The average is 3.75 which we truncate to 3.

Similarily, the air stations equipped with three C-130's have:

Number Available	Percent Time
3	42
2	42
1	14
0	2

This means three C-130's can be expected only 42% of the time.

Lastly, there is San Francisco Air Station with two C-130's. There we have:

Number Available	Percent Time
2	56
1	38
0	6

At this air station, the number of C-130's is critically low for the delivery of ADAPTS. This will be shown in the following chapters.

The other factor which seriously affects the ability to deliver the ADAPTS equipment in a timely fashion by C-130 is the method of loading the C-130. The ADAPTS equipment which is described in the following sections of this chapter is large and heavy. With proper ground handling equipment and rail systems in the C-130, it can be loaded in ninety minutes (estimated), otherwise, the loading process may take over 120 minutes. Of crucial importance is the time required to fully prepare the C-130 for loading.

The sixth C-130 stationed at Elizabeth City, N. C., is equipped with an electronics pod which takes over eight hours to remove; for this reason is not available for the delivery of the ADAPTS equipment. The remaining five C-130's must be modified for use by installing rails that allow the loading and air dropping of the ADAPTS equipment. Depending upon the type of rails and the modifications initially made to the C-130, the rail installation process requires 15 minutes to four hours before the C-130 is ready for loading.

The Helicopters

The Coast Guard fleet of helicopters includes two types useable for ADAPTS. They are located in the East as follows:

Air Station	Type	Number
Cape Cod, Mass	HH-3F HH-52A	3 3
Elizabeth City, N.C.	HH-52A	3
Brooklyn, N. Y.	HH-3F HH-52A	3 4
Cape May, N. J.	HH-52A	2
Savannah, Ga.	HH-52A	2
St. Petersburg, Fla.	HH-3F	4
Miami	HH-52A	4

They are located in the West as follows:

Air Station	Type	Number
Annette, Alaska	HH-52A	3
Astoria, Oregon	HH-52A	2
Barbers Point, Hawaii	HH-52A	2
Kodiak, Alaska	HH-52A	2
Los Angeles, Calif.,	HH-52A	2
Port Angeles, Wash	HH-52A	3
San Diego, Calif.	HH-3F	4
San Francisco, Calif.	HH-52A	4

The operating parameters used in the study for [illegible] are:

Parameter	HH-3F	HH-52A
Average Speed to scene (knots)	115	[illegible]
Average Speed from scene (knots)	12[illegible]	[illegible]
Carrying capacity (pounds) of fuel and cargo	7,[illegible]	2,[illegible]
Reserve fuel (pounds) for half hour safety factor	[illegible]	[illegible]
Average refueling time (minutes)	[illegible]	[illegible]
Average fuel consumption (pounds per hours)	1,100	[illegible]
Number of equipment packages carried per trip	1	[illegible]

From the above, it is deduced that the HH-52A can [illegible] for limited purposes up to [illegible] miles while the HH-3F can be used for [illegible] up to 100 miles and for limited purposes up to [illegible] miles from its air station. These limitations are built into the models described in Volumes 2 and 3 of this report. Because of the range limitation and the wide spacing of the air stations, there are areas of the coast which can not be reached in a timely manner by helicopter. In some instances the ferrying of HH-3F's to an air station that has only HH-52A's will be necessary. An example will be to provide HH-3F's to work at a scene near Wilmington, North Carolina.

In order to carry cargo, the helicopters must have slings and sling [illegible] attached; this can require several hours if a [illegible] not previously fitted to the helicopter. This study [illegible] will be accomplished before the need to use the sling [illegible] HH-3F

helicopter can carry a whole equipment package while the HH-52A can lift one only if it is nearly empty of fuel. Hence the concept of a third of an equipment package was evolved for evaluation of the capability of the HH-52A; it must be realized that the equipment package would require redesigning to be packaged into thirds. Whether this is necessary depends upon the planned service life of the HH-52A and the planned deployment of the HH-3F to CG Air Stations. At present, such a package appears necessary.

The helicopter aircrews are limited to 6 hours flight time by the Air Operations Manual, CG-333, but unlike the C-130, the helicopter is necessary only during the initial four to six hours of the deployment; thereafter, boats can be used in lieu of helicopters provided, a large oil slick has not formed (potential fouling of the boat engines). This air crew restriction is not as limiting as the range of the helicopters.

One Hour Helicopter Coverage
on the East Coast

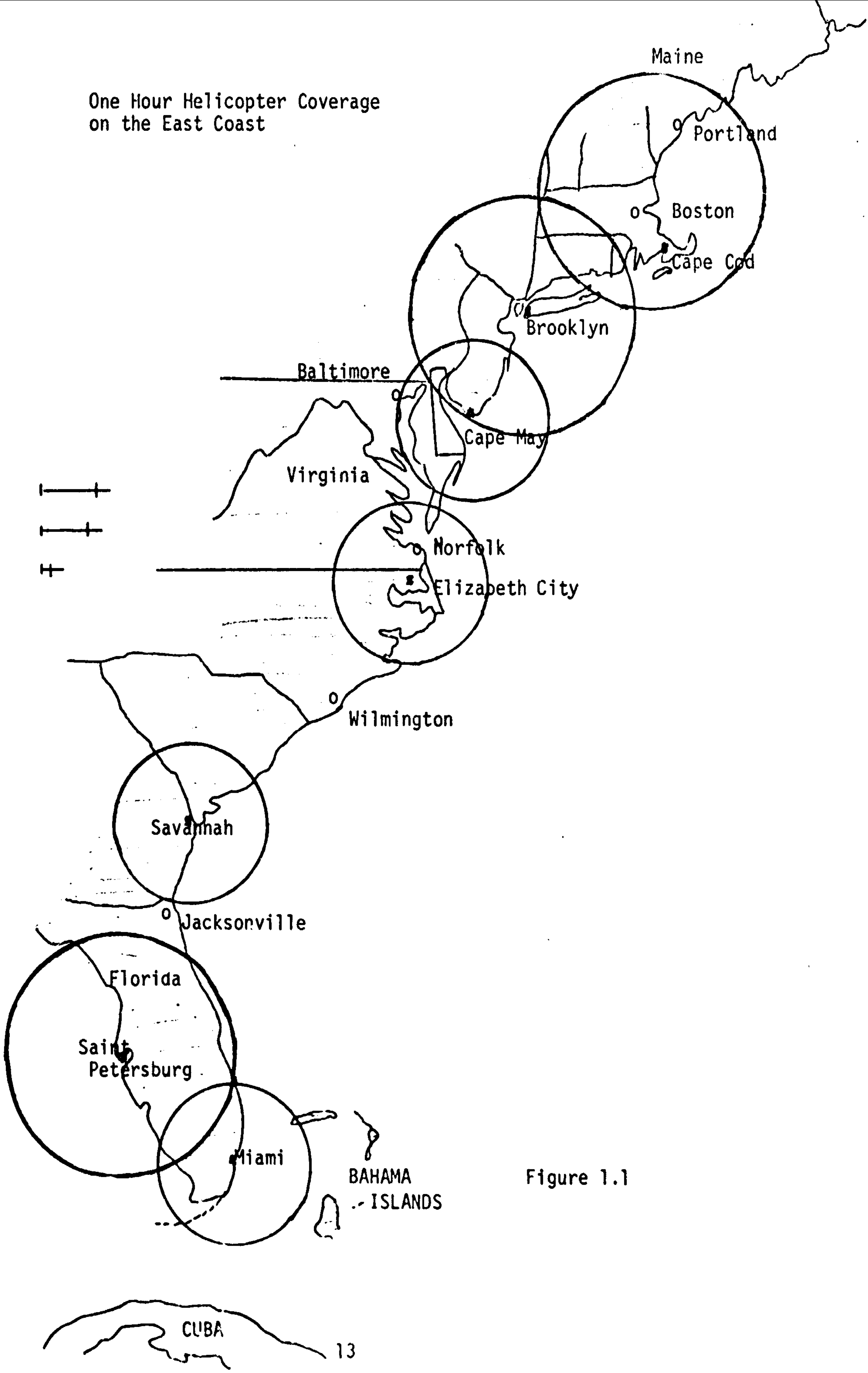

Figure 1.1

The ADAPTS Packages

There are two type of packages used by ADAPTS for rapid delivery of equipment by C-130 to the scene from a central storage. These are the bag package (tank package) and the equipment package. The equipment package, when modified by removal of the parachutes and rigging needed for C-130 delivery and air dropping, can be delivered by an HH-3F helicopter in many instances. The following is a list of the individual components, their weights, and their sizes for the prototype system:

ITEM	DIMENSIONS	WEIGHT
Oil Storage Container (bag) with Hose and Fittings	Folded 5'[illegible]" x 7'0" x 6'2"	[illegible],583 lbs.
Capacity [illegible] gallons	Filled 140' x 30' x 6'	500 tons
Bag Module (including flotation, side plates, bindings, and bag)	7'0" x 7'4" x 8'0"	10,[illegible]12 lbs.
Diesel Engine Module (including enclosure and flotation)	3'4" x 3'7" x 4'0"	1,150 lbs.
Pump Module (including enclosures, pump, flotation, and hydraulic hoses)	2'4" x 2'4" x 6'10"	946 lbs.
Pump alone	5" diameter x 6'10"	4[illegible]5 lbs.
Flexible [illegible] Fuel Container ([illegible] gallons)	Filled 2' diameter x 2'10"	4[illegible] lbs.
[illegible] Module (A-Frame) ([illegible])	2'1" diameter x 10'3"	270 lbs.

The bag consists of a thin-walled discharge hose connected to a seaworthy rubberized nylon container. The flexible oil storage container has a capacity of 140,000 gallons or approximately 500 tons of crude oil It is made of 13 ounce/square yard nylon fabric coated inside and out with nitrile compounds. The container is filled through a six inch flexible hose 300 feet long which is delivered with the container. Butterfly valves are fitted at both ends of the hose. The container is provided with enough closed cell foam to keep it afloat before it is filled with oil. Vents are fitted to prevent the accumulation of explosive vapors. Once filled, the bag is towed to sheltered waters using a towline which is air-dropped with the container.[1] In addition to being configured for towing from one end, the bag is fitted with several attachment points for mooring lines, etc.

The basic equipment package consists of a diesel engine close-coupled to a hydraulic power supply, a hydraulically driven cargo transfer pump, a fuel supply, a flow meter, and ancillary equipment for handling the machinery over the side of the ship and on deck. To this is added the packaging necessary for helicopter or C-130 delivery.

The cargo transfer pump is a two stage mixed flow submerged turbine type capable of delivering 1000 gallons per minute of a medium weight crude oil against a head of 60 feet. The prime mover is a 44 horsepower four cylinder, air cooled Diesel engine driving a 30 gallon per minute hydraulic pump. The cargo transfer pump may be operated at a distance from the prime mover since it is connected by 80 foot long, flexible high pressure hydraulic hoses equipped with quick disconnect fittings.

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[1] This study was limited to operational deployment to the scene. The recovery of the equipment including the filled bags was not studied.

Ancillary equipment provided in addition to the basic components consists of an A-frame, fuel tank, and flow meter, as well as necessary tools and fittings. The A-frame is used for lifting the pump, engine, and fuel modules from the water onto the deck of the tanker. Later, it is used to lower the pump into the ship's tank and to support the pump during the pumping operations. The A-frame is equipped with a two-speed, hand cranked winch and adjustable wire stays; it is often refered to as a Hauling and Lifting Device (HLD) in this report. The flow meter is a turbine type mounted in the oil transfer hose. A signal cable connects the turbine unit to the flow indicator unit. This unit indicates both flow rate and the total amount of oil transferred. The fuel container is a 55 gallon flexible rubber cylindrical container. This is sufficient for over 10 hours of full power operation.

For air delivery the packages include parachutes, rigging, pallets and anchors which are necessary to deliver the ADAPTS equipment to the ocean surface from the C130 aircraft. All equipment is designed and packaged to survive the shock loadings of parachute opening and water impact. The packages are self-anchoring and positively buoyant and will float indefinitely after delivery. The deployment techniques and operating procedures for this system have been proven in full scale system tests in calm seas. The equipment has been designed for a minimum of maintenance and simplicity of operation. All components are designed for reuse. For air delivery, the system components are loaded on [illegible] x 12 foot pallets. The maximum height of each load on its pallet is eight feet. A complete oil storage container pallet currently weighs 13,700 pounds (the desired weight is 13,[illegible] pounds or less) and the complete pumping system [illegible] [illegible] The pallets are designed for [illegible]

the use on the C-130 aircraft rail systems. A lighter packaging is being considered for delivery of the pump and other equipment modules (except the bag) by helicopter. For C-130 aircraft delivery a tank package requires:

ITEM	AMOUNT
bag and hose	1
pallet	1
G 11A parachutes	2
extraction parachute	1
anchor	1
boxing	4 sides and a top

straps, rigging, and pyrotechnic releases.

The equipment package requires the same materials except that it needs only one G 11A parachute. A complete equipment package (based upon the prototype) will cost around $11,200 when configured for delivery by a C-130 aircraft and around $8300 when configured for delivery by helicopter. The bag package will cost around $46,200. It is hoped that the unit price will drop when large scale purchasing is done.

The Salvage Teams and Their Life Support Equipment

In the testing of the prototype ADAPTS, there were many of the manufacturer's personnel as well as Coast Guard Personnel used. Often there were twenty persons there to handle the single prototype equipment package and the single prototype bag package. An analysis of the tests performed showed that only three trained men are needed at any time to perform the tasks of hauling in, setting up a pump, and filling a tank. Since the deployment of ADAPTS is a twenty four hour operation, an additional man is considered necessary to allow for meals, rest, and other off time. Hereafter in this report, the term salvage team will refer to the four men team necessary to set up and operate a pump. It will be assumed (unless otherwise stated) that there is a salvage team for each pump used at the scene. Note that a four man team can be delivered as a unit by helicopter.

Many of the potential spills for which ADAPTS will be deployed will require a large number of pumps and consequently a large number of men at the scene, for example, six pumps and 24 men (6 salvage teams). For an operation of this size, not all of the pumps can be delivered in the first six hours and not all of the men will be needed until all of the pumps are at the scene. The first men delivered will do the bulk of the setting up while the later men will do the major part of the bag filling and towing. These men will require support equipment so that the operation can be conducted at night and in poor weather.

The support equipment will include:

ITEM	UNIT
wet suit	one per man
life jacket	one per man
foul weather gear	one per man
sleeping bag	one per man
rations and water	about 3 days per man
lighting plant	1 or more
radio, portable	1 or more

The packaging, stock piling, and delivery of this equipment is not considered in this study.

CHAPTER 2

METHOD OF STUDY

The study was conducted in several well defined stages. The first stage was the definition of the problem and the definition of the study parameters and assumptions; this included data collection. The second stage was the building of models that accurately describe the deployment of ADAPTS. This stage included acquiring new data and verification of the models. The third stage was the operation of the models and the use of the data thereby generated along with the earlier data:

a. to list the most likely results of deploying ADAPTS (assuming favorable weather, etc).

b. to determine the equipment requirements,

c. to determine the best mix of equipment, to be purchased on first year funds, and

d. to determine the incremental benefits of adding a unit of equipment

A final stage was the reporting of the progress of the study including this report.

The objectives of the study included defining the operating parameters of ADAPTS and determining the incremental benefits of Coast Guard resources. This was specifically for the first year procurement of ADAPTS for East Coast Coverage; the study was later expanded to the West Coast between Mexico and Canada. The operating parameter and incremental benefits that were defined apply, however, to any area, provided there is no change in the equipment used.

Definition of the Problem

An examination of the large spills that occured in the 1960's indicates that an average spill of 15,000 tons of oil can be expected to occur on the East Coast of the United States roughly twice a year if the current rate of spill continues. Table 2.1 lists where and how often these spills have occured; it is derived from Coast Guard records; testimony given before the Committee on Public Works, U. S. Senate, February through June 1969 and; a paper given by D. D. Smith et al. (Dillingham Corporation) at the Industry Government Seminar on Oil Spill Treating Agents in April 1970. A comparison of the observed frequency of spills with the frequency of oil cargo traffic on the East Coast shows the hypothesis that the percent of the oil traffic (given location on the East Coast compared to the East Coast as a whole) is a good indication of the probability of an oil spill at a given location is false.[1] Because a good fit can not be established between the two distributions, there is no method other than by use of historical files and projections by which a spill probability in a given location can be derived. This method failed due to the incomplete reporting of spills during the past decade. In a significant number of reports, the report indicated a spill of unknown size and cause. Because of these deficiencies in the ability to predict the need for ADAPTS (we can state only roughly 15,000 tons once or twice a year on the East Coast), the problem is defined in terms of what can be done, not in terms of what must be done.

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[1]The Chi-Square test gave a value of [illegible] .11 when it should have been less than 5.00.

TABLE 2.1

COMPARISON OF LARGE SPILLS TO OIL TRAFFIC

Location	Number of Spills in 10 Years	Observed Frequency	%Oil Cargo Traffic
Portland, Me.	0	0	.06
New York, N.Y.	3	.176	.32
Delaware Bay	3	.176	.19
Florida Straits	1	.059	.20
Boston, Mass.	0	0	.05
Chesapeake Bay	1	.059	.05
Narragansett Bay	3	.176	.02
New London, Conn.	2	.117	.02
Savannah, Ga.	0	0	.02
Jacksonville, Fla.	1	.059	.02
Miami, Fla.	0	0	.20
Tampa, Fla.	1	.059	.20
Elsewhere on East Coast	2	.117	.01

For the reason of weather noted in the Introduction, the deployment of ADAPTS must be rapid and in large quantities of equipment. For this reason the measure of effectiveness is how many bags can be filled in twenty-four hours. Thus the problem of oil spill prevention is defined as:

When a large quantity of oil is about to be spilled from a ship can ADAPTS be used to prevent the spill? How much can ADAPTS handle in 24 hours? Where should the ADAPTS equipment be located? How much equipment should we buy and what other equipment do we need?

The problem as defined required the establishment of many simplifying assumptions in addition to the characteristics and parameters of the equipment. The first assumption was that it is sufficient to investigate the capability of ADAPTS at the following key locations on the East Coast:

Name	Body of Water	North Latitude	West Longitude
Portland, Me.	Casco Bay	43 42'	7[illegible]° [illegible]'
New York City	New York Harbor	40° 42'	74° [illegible]'
Cape May, N. J.	Delaware Bay Entrance	3[illegible]° [illegible]'	7[illegible]° [illegible]'
Norfolk, Va.	Chesapeake Bay	37° [illegible]'	76° [illegible]'
Key West, Fla.	Florida Straits	24° [illegible]'	81° [illegible]'

Several intermediate positions were established on the East Coast to investigate the effect of changed helicopter distances with constant C-141 distance to provide intermediate points on some graphs; these include Buzzards Bay, Atlantic City, Baltimore, [illegible], Nantucket Shoals, Cape Lookout, and two locations off Miami.

The key locations selected for the West Coast are:

Name	Body of Water	Latitude	Longitude
Los Angeles	off Palos Verdes Point	33° 40'	118° 20'
San Francisco	off Point Reyes	38 00	123 00
Seattle	Puget Sound	47 30	122 30
Port Angeles	Strait of Juan de Fuca	48 [illegible]	123 53
	Strait of Juan de Fuca	48 30	124 40

These positions were selected because they gave a good spread of distances from the C-130 equipped air stations and there was a dense oil tanker traffic; they were not chosen on the basis of a high probability of an oil spill.

Other simplifying assumptions made include:

- no equipment failures
- a C-130 is always available with rails installed
- once available, C-130's remain available until the end of the 24 hour period regardless of scheduled maintenance
- there are enough aircrews to fly the available C-130's for 24 hours (some examples of relaxing this assumption are given).
- there is no outside help from the tanker crew, from commercial salvage firms, or from Coast Guard Cutters. That is, ADAPTS stands alone.
- weather does not prevent system delivery and operation (see Chapter [illegible]).
- a C-130 carries [illegible] ADAPTS packages per trip.
- the present ADAPTS characteristics apply.
- the first [illegible] at an air station can take off immediately and [illegible] can take off one hour after it is [illegible].
- there are enough air crews to operate helicopters for 24 hours.

In addition to the previously given characteristics of aircraft and equipment, the operational parameters established by the Coast Guard for its aircraft, and the above assumptions, several parameters were established for the purpose of this study. The first is that there are two types of rails available for use in C-130's and that the mean time to install the first, labeled -4 rails, is four hours. Once a C-130 has been modified to accept the second type, labeled -4A rails, the -4A rails can be installed in 15 minutes. Except for a ready C-130, all C-130's must have the rails installed before they can be used to deploy the AMPTS packages.

Another parameter established for this study was that only two methods of loading a C-130 will be considered. The first involves using a flat bed with rails fastened to the bed; this makeshift loader requires about two hours to fully load a C-130. The second is a special purpose self propelled loader, labeled the 25K loader, which was designed for use with the C-130; the 25K loader is estimated to require about 90 minutes to load a C-130. Also the 25K loader has features which reduce the chance of damaging the aircraft during the loading process. Other methods of loading the C-130's exist; they may be substituted for these with little effect to the results of this study. A final parameter established is that the refueling of the C-130 occur concurrently with the loading of the C-130.

The Building of the Models

Volumes 2 and 3 of this report describe how the model building progressed from data collecting to the process of using PERT/CPM networks to describe the ADAPTS deployment. From the results of that step, a simulation model was built to investigate the siting of the salvage teams, the use of the different types of rails, loaders, etc. A simpler, mathematical model was built near the end of the study; it allows the deployment of ADAPTS to be run on the Coast Guard Computer.

CHAPTER 3

RESULTS OF THE STUDY

The successful operational deployment of ADAPTS is highly dependent upon the early availability of C-130's and helicopters. The numbers of these aircraft, the time they first are available for use, the length of time they are available, the time of loading, the distances involved and the strategies (command decisions) of deployment interact in a highly non-linear manner to severely limit the results obtainable. It is imperative that rapid response be made to the call to use ADAPTS. This means, especially when the scene is distant from Elizabeth City on the East Coast (any scene on the West Coast since San Francisco has only two C-130's), being willing to recall personnel and sortie aircraft immediately without waiting to verify whether the reported incident is a true case. Of course when twenty four hours are not a constraint, the need to scramble diminishes. The following sections indicate what can be done with the resources available and what incremental improvement can be obtained by adding another unit of a given resource. The reader is cautioned that the incremental benefit obtained from an additional unit of a given resource is not constant; it varies with the constraints imposed by the other resources. For example if there are two 25K loaders and five C-130's, adding a sixth C-130 will provide no additional benefit for distances less than 375 miles.

Costs

The costs in Table 3.1 are compiled from budgetary documents, purchases of prototype equipment, and informal estimates from Ocean Engineering Division and Applied Technology Division. They are sufficiently accurate for the purposes of this study but cost estimates should be obtained from the Office of Engineering for budget preparation.

In deriving the cost of the system, the costs of personnel and facilities, that already exist for other purposes, are treated as sunk costs; that is, the decisions to buy and to use ADAPTS do not affect paying for them; hence, the sunk costs are ignored.

The costs of an oil spill are hard to estimate since they vary not only with the scale of the spill but also with the location and with the effort made to control and clean up the spilled oil. For the average large spill the cost is near $300 per ton of oil actually spilled. This can vary from zero to several thousand dollars but the $300 figure is the currently obtained average. The average East Coast spill (in the catagory of spill which ADAPTS is designed to prevent) is 15,000 tons of oil at an average distance of 360 miles from Elizabeth City Air Station (derived from Table 2.1).

C-130 Aircraft

The following figures represent the best possible results obtainable from a given number of C-130's with the scene varying. Note that these results are obtained by having:

- o enough aircrews for 24 hour operations,
- o enough loaders so that a C-130 never waits,
- o enough helicopters so that work at the scene is never delayed,
- o enough pumps so that bags are not waiting, and
- o the salvage teams stationed at Elizabeth City Air Station. In other words, figures 3.1 through 3.5 give the theoretical best results for the C-130 resource. Figure 3.6 combines the results of the proceeding figures.

TABLE 3.1

Costs of ADAPTS in Dollars

Item	Unit	Purchase Cost	Annual Cost
Communication and Lighting subsystem	Package	53,000	?
Equipment Package			
helicopter delivery	ea.	12,600	?
C-130 delivery	ea.	18,600	?
Bag Package	ea.	46,000	?
Aircraft			
C-130	ea.	3,550,000	424,300
HH-3F	ea.	2,330,000	285,500
HH-52A	ea.	500,000	161,000
C-130 Loader			
25,000 pound type	ea.	37,500	?
10,000 pound type	ea.	surplus	?
Personnel support	per man	200-300	?
Pilots, Fix Wing	ea.	22,000*	20,000
Crewmen	ea.	300*	8,500
Salvage team officer	ea.	800*	16,700
Salvage team enlisted	ea.	200*	7,700
HH-3F cargo slings	ea.	11,000	
C-130 rails			
-4	set per C-130	20,000	
-4A (incl plane mod.)	set per C-130	67,000	(per plane for one)
		52,000	(per plane for three)
		40,000	(per plane for five)
		30,000	(per plane for 15)

*Training

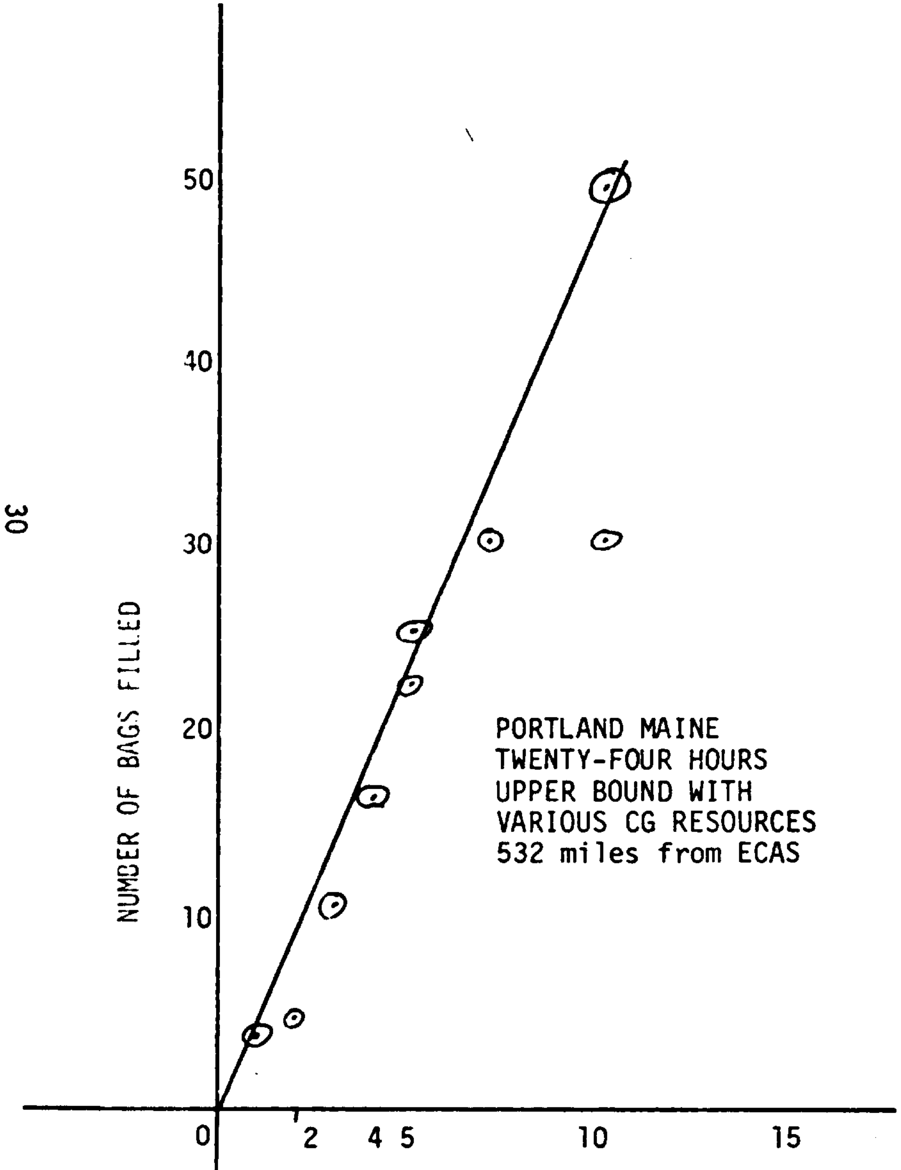


Figure 3.1

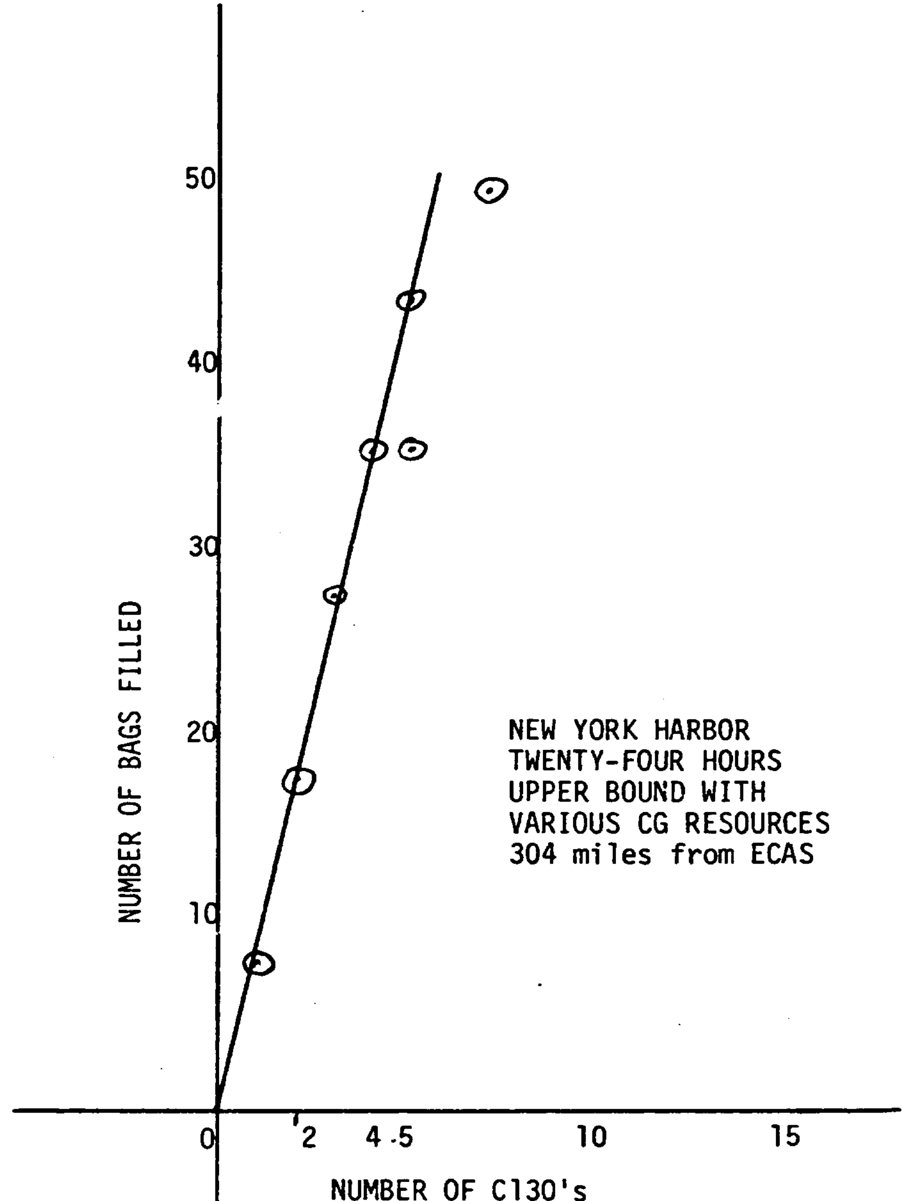


Figure 3.2

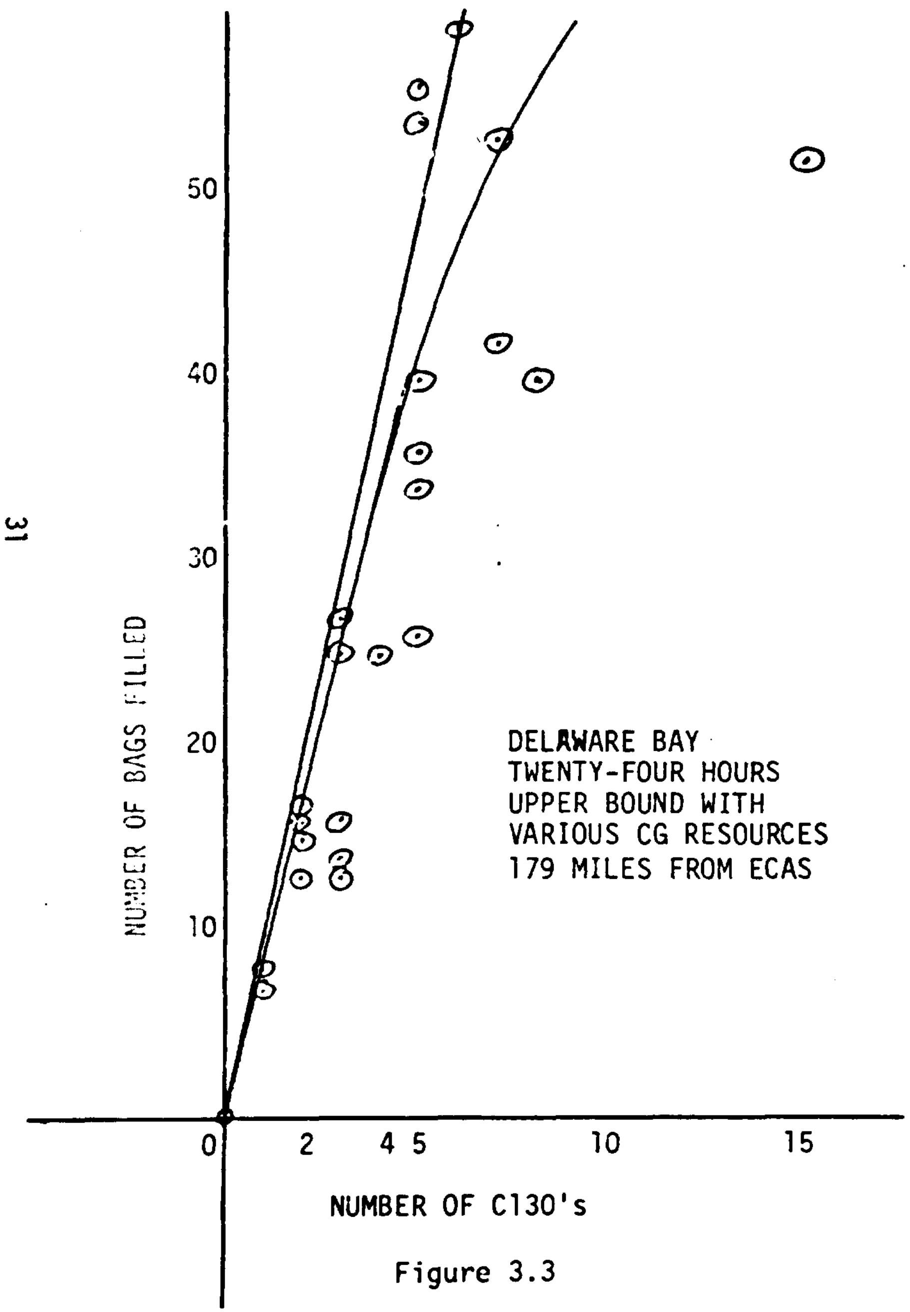


Figure 3.3

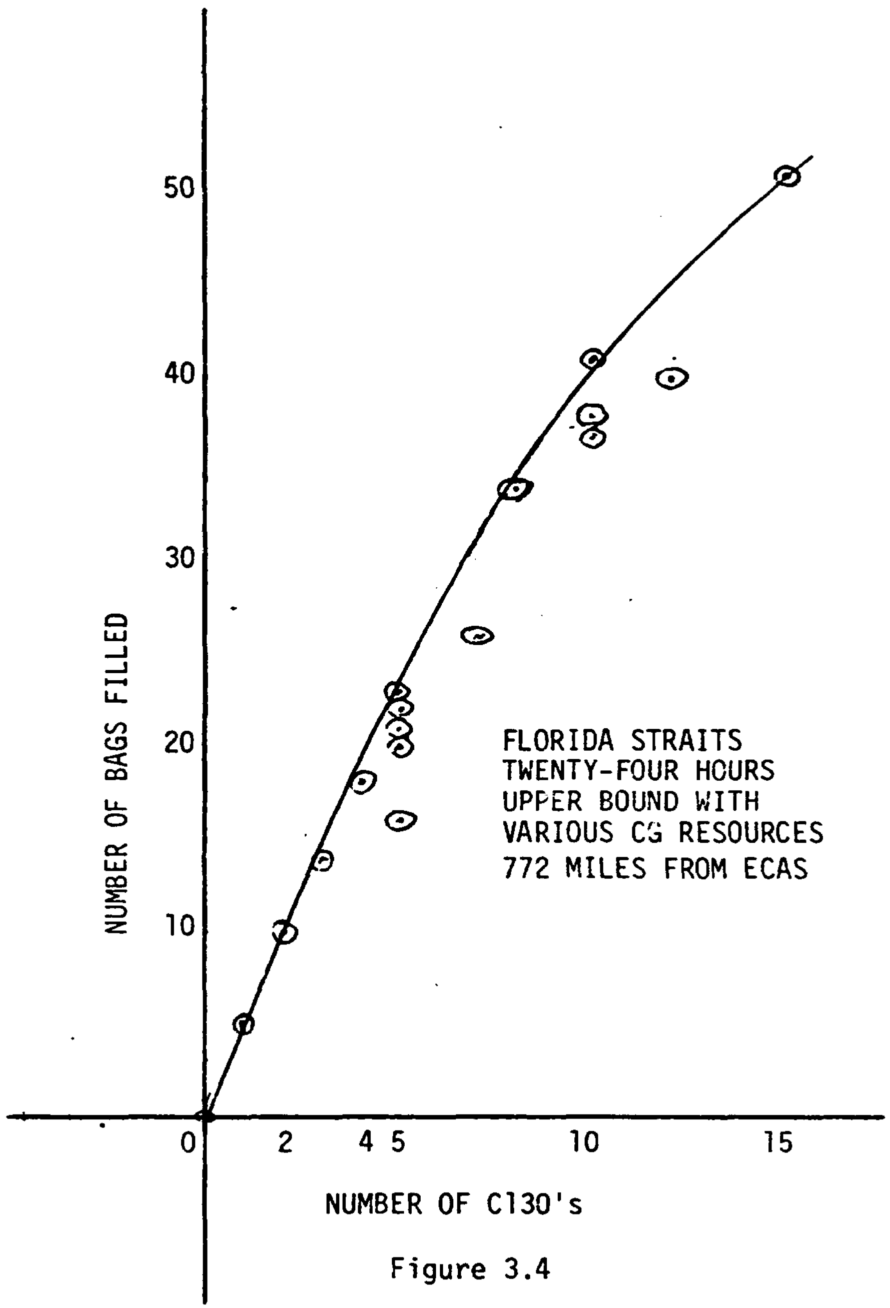
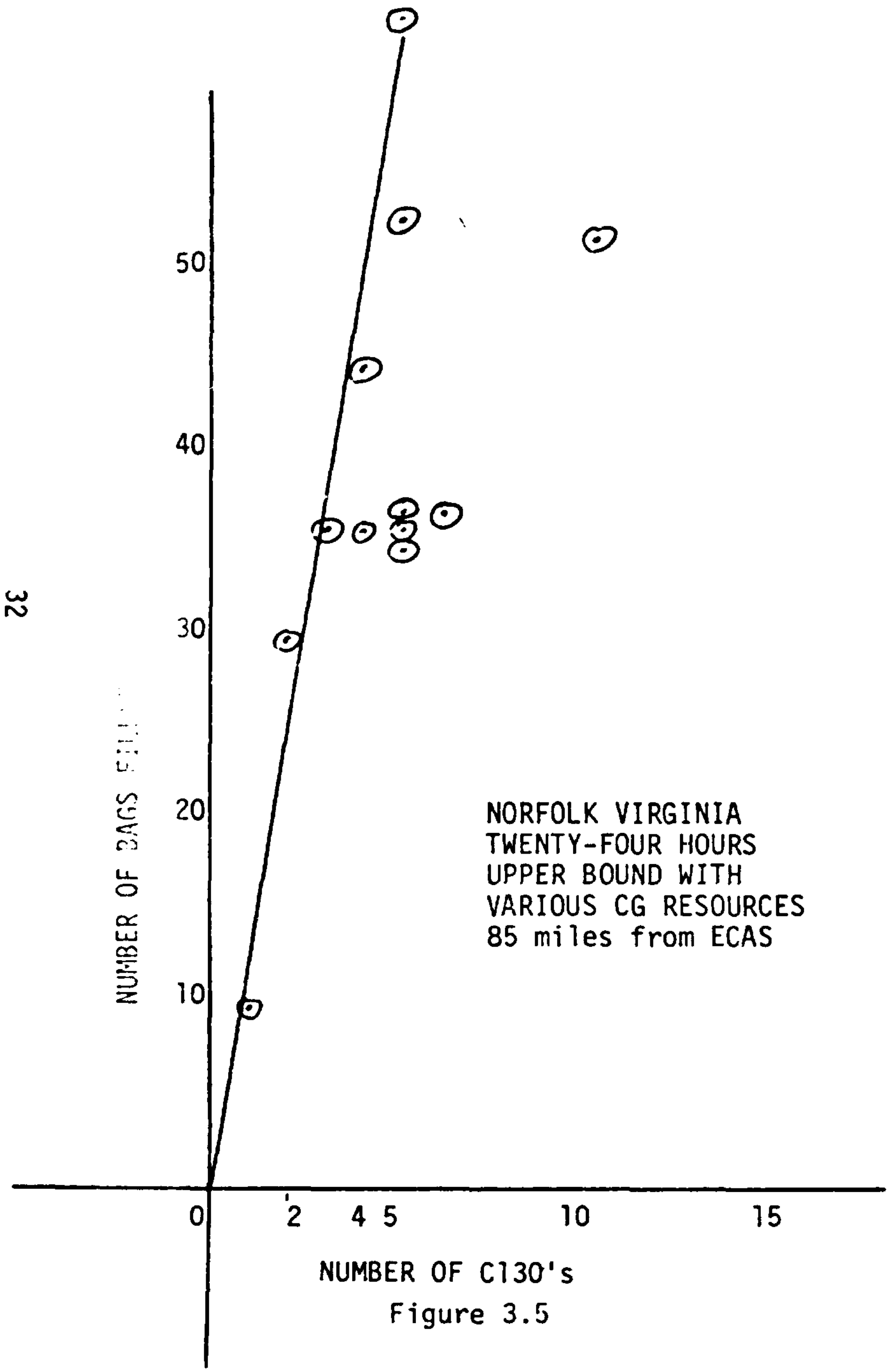
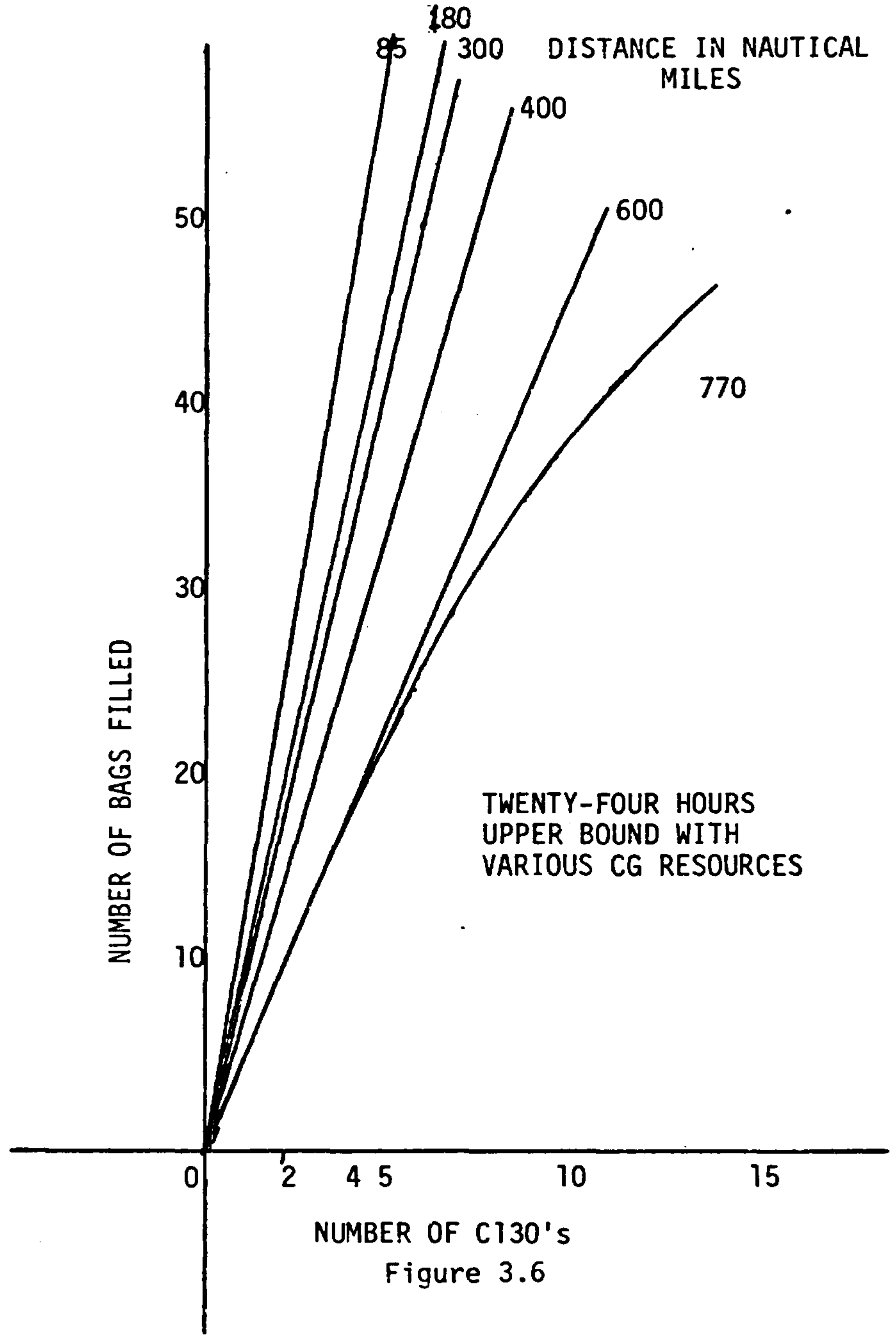


Figure 3.4



NUMBER OF C130's
Figure 3.5



NUMBER OF C130's
Figure 3.6

C-130 Air Crews

While the average large spill, for which ADAPTS could have been used in the past decade, was 15,000 tons (30 ADAPTS bags) and the average distance from ECAS to the scene for these spills being around 360 miles, it is clear from table 3.2 that five C-130's with seven air crews[1] will be able to deliver only 22 bags which can be filled within the 24 hour period. This is seventy per cent of the number required to completely contain the average spill. Using the reasoning that most of the spill can be avoided by using ADAPTS, it is clear that seven air crews can be used effectively nearly every time ADAPTS is needed and that eight crews can be used effectively at least half the time.

From Commandant's Notice 7100 dated 25 February 1971, subject Annual Standard Personnel Costs, the initial cost of three pilots and six crewmen for a C-130 is $65,580.00 and the annual reoccuring cost is $110,895.00. The time that these personnel would be assigned to flight duty involving C-130's, during a twenty year career, would be high, certainly around eight to ten years. If the initial cost is spread over six years, two tours of duty to be conservative, the resulting annual cost is $121,825.00. The Special Operational Requiremen[illegible] R) for ADAPTS of 31 March 1971[2]

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[1]This assumes that ADAPTS is treated as a logistic operation and that 10 hours flight time is allowed for the C-130 air crews per CG-333, The Air Operations Manual.

[2]See OLE-3 memo to E, file 5922/4a dated 3/31/71.

TABLE 3.2

Number of Bags Filled in Twenty-Four Hours*

Five C-130's and Two 25 K Loaders

Air Crew Endurance in Flight Hours	24	8	8	8	8	10	10	10	10	12	12	12	12
Number of Crews	5	5	6	7	8	5	6	7	8	5	6	7	8
Miles From ECAS	Number of Bags Filled												
85	50**	24	30	36	42	34	42	50	50	38	46	50	50
133	50	20	26	32	38	30	38	44	50	32	38	44	50
179	48	20	26	30	34	24	30	36	42	28	34	40	46
180	48	20	26	30	34	24	30	36	42	28	34	40	46
200	48	14	18	24	30	24	30	36	42	28	34	38	42
304	44	10	14	18	22	18	22	26	30	20	26	30	34
400	36	10	14	18	22	14	18	22	26	18	22	26	30
532	30	8	10	12	14	10	14	18	22	14	16	20	24
656	24	4	6	10	14	10	14	16	18	10	14	18	22
772	20	4	6	8	10	8	10	12	14	10	14	16	18

* - 4A rails, 6 salvage teams, 6 pumps, 3 HH-3F helicopters.

** This amount of C-130's and 25 K loaders cannot deliver more than 50 bags in time for the bags to be filled within 24 hours from time Coast Guard is first notified.

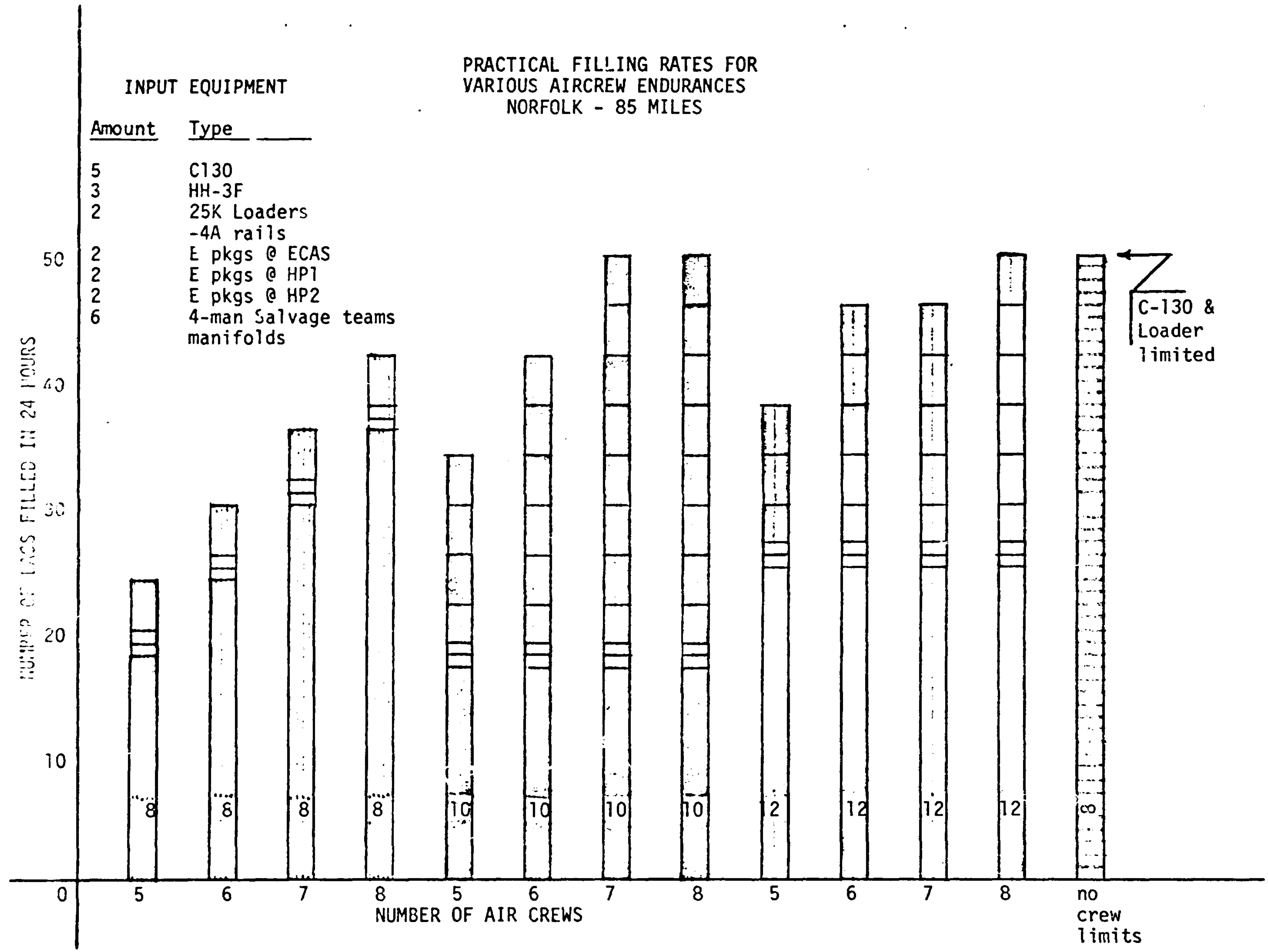

PRACTICAL FILLING RATES FOR
VARIOUS AIRCREW ENDURANCES
NORFOLK - 85 MILES
INPUT EQUIPMENT
Amount Type
5 C130
3 HH-3F
2 25K Loaders
-4A rails
2 E pkgs @ ECAS
2 E pkgs @ HP1
2 E pkgs @ HP2
6 4-man Salvage teams
manifolds
NUMBER OF LACS FILLED IN 24 HOURS
0
10
20
30
40
50
8
8
8
8
10
10
10
10
12
12
12
12
∞
C-130 &
Loader
limited
5
6
7
8
5
6
7
8
5
6
7
8
no
crew
limits
NUMBER OF AIR CREWS

Figure 3.7

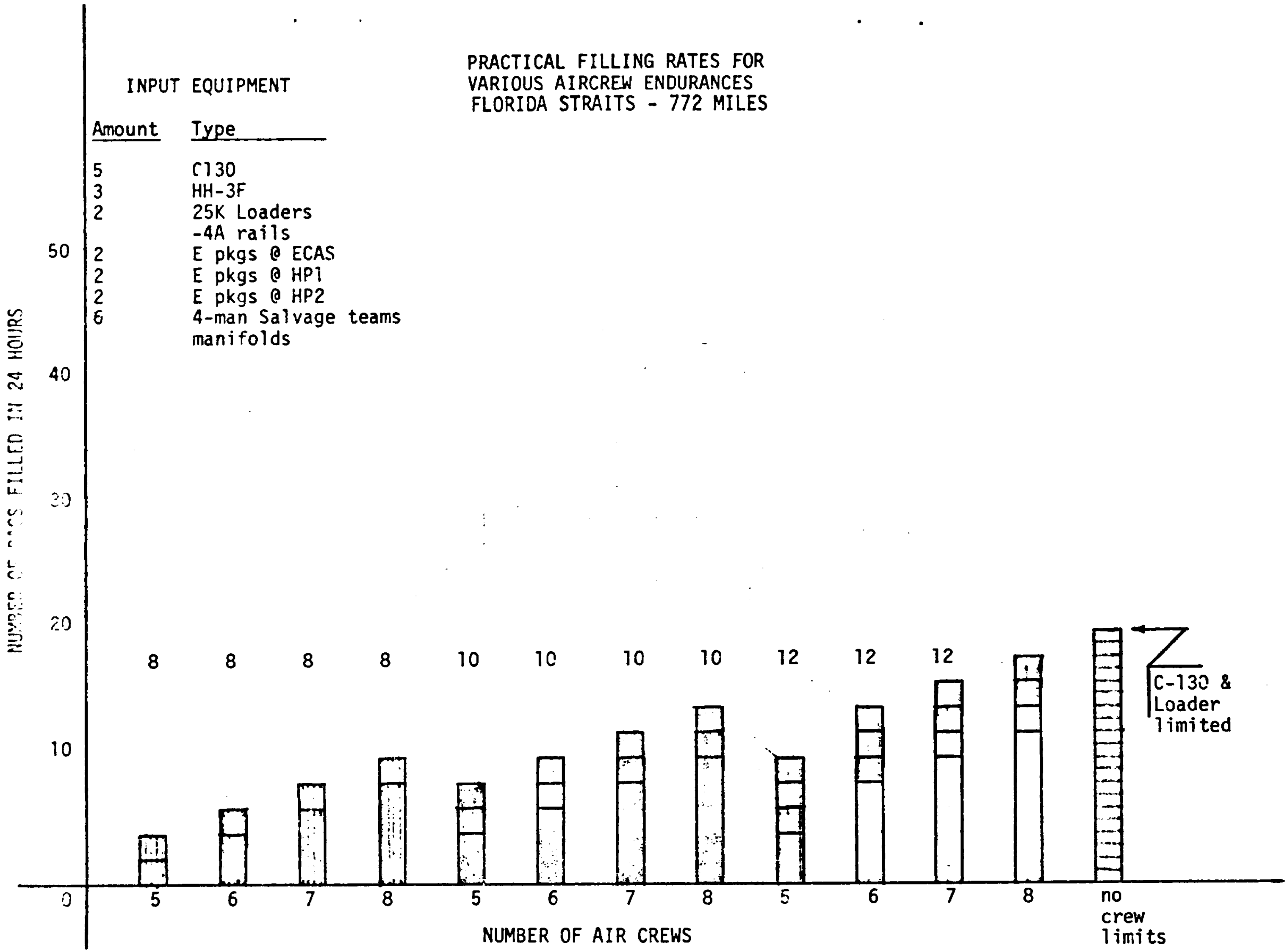

PRACTICAL FILLING RATES FOR
VARIOUS AIRCREW ENDURANCES
FLORIDA STRAITS - 772 MILES
INPUT EQUIPMENT
Amount Type
5 C130
3 HH-3F
2 25K Loaders
-4A rails
2 E pkgs @ ECAS
2 E pkgs @ HP1
2 E pkgs @ HP2
6 4-man Salvage teams
manifolds
0
10
20
30
40
50
8
8
8
8
10
10
10
10
12
12
12
5
6
7
8
5
6
7
8
5
6
7
8
no
crew
limits
C-130 &
Loader
limited
NUMBER OF AIR CREWS

Figure 3.8

places the cost of clean up for the average large spill at $300 per ton of oil. Table 3.2 shows that an additional C-130 air crew is worth four additional bags delivered and filled within 24 hours. At 600 tons of oil contained per bag, this is 2000 tons of oil not spilled and an avoided clean up cost of $600,000.00. It can be seen that a full air crew pays for itself if used only once per year on ADAPTS.

When each C-130 was purchased, four commissioned pilots and 21 enlisted crewmen were programmed. ECAS with five C-130's (the electronics plane is ignored) could have up to 20 pilots and 105 crewmen. At three pilots plus six enlisted crewmen per air crew, this comes to six air crews because of pilots; it is assumed that from this number of enlisted crewmen, enough have varied skills to make up at least eight air crews and have still more available for the next day's operations. With this configuration of pilots and crewmen each air crew has eight hours flight time.[1] Table 3.2 shows that at least eight full flight crews are needed; this means that six more pilots should be programmed at an average cost of $141,050.00 per year (initial cost spread over six years).

If four pilots are assigned to each air crew, the flight time endurance can reach 12 hours but the ten hour figure given earlier is more realistic.[2] Under this configuration, the results are as given before and six additional pilots are still required so that seven air crews can be formed. Note that five C-130's with seven air crews enduring 10 hours each are superior in results to five C-130's with eight air crews enduring 8 hours each for most distances.

[1,2]See CG-333.

Based upon this analysis, six additional commissioned pilots are recommended for ECAS. Please note that this analysis allows for only two ineffectives (leave, etc.) from the original 20 pilots allowed and that it is dependent upon having the other resources identified in the footnote to table 3.2.

Figures 3.7 and 3.8 are derived from Table 3.2 to show graphically the results of deploying ADAPTS to Chesapeake Bay near Norfolk Virginia, and to the Florida Straits near Key West. These figures give the results that can be expected during good weather and during that 24% time that five C-130's are available.

C-130 Loaders

The primary considerations with loaders are that the loading of the C-130 take as little time as possible commensurate with safety for the aircraft and the loading personnel. Another consideration is that the loader be reliable.

This study was limited to two loaders although others exist. The two are the converted flat bed which we will call the makeshift loaders and the 25K loader. The fact that the converted flat bed is not an equipment designed and tested for the task is indicative that its safety and reliability are questionable; experience shows that, without major problems, it can load the C-130 in 120 minutes. The 25K loader is specifically designed for the task of loading an aircraft such as the C-130; however, it is not currently available for purchase. If it becomes

TABLE 3.3

Comparison of Number and Type of Loaders

Computer Run #	Number C-130's	Number of Loader	Loaders Type	Bags Filled in 24 Hours	Waits For Ldr	Average Wait (Minutes)
AAE	2	1	Makeshift	15	8	2[illegible] [illegible]irst [illegible]gs)
BBF	2	2	Makeshift	16	0	0 "
BBD	7	5	Makeshift	42	3	42
CCJ	7	5	25 K	53	2	36
ACA	5	2	25 K	36	31	36
ACC	5	5	25 K	36	0	0

available, it is estimated to use 90 minutes in loading a C-130. The desireability of the 25K loader is illustrated by Table 3.3; note that other resources which are not listed could be restraining the larger result of each pair. This is true for the last pair where there were not enough equipment packages. In that instance while the number of waits for loaders dropped to zero, the number of waits for equipment packages increased from 57 to 68 and the average wait for an equipment package reached 236 minutes, nearly four hours. A comparison of computer runs [illegible]1 and DBM showed that three makeshift loaders produced four waits averaging 46 minutes while two 25K loaders produced 32 waits (a drastic increase) averaging 43 minutes (a minor decrease).

Table 3.4 shows how the need for loaders decreases as distance increases. Note that the maximum of 36 bags in 24 hours is reached due to the number of equipment packages and the number of loaders. Run DBM1 indicates the extent of the equipment package limitation when compared against run DBM.

Since with five C-130's, we can obtain the desired 40 bags in 24 hours (36 bags if only one air station can deliver prepositioned equipment packages by helicopter) with only two loaders within 300 miles of Elizabeth City Air Station and since beyond that distance it is the number of C-130's that is constraining and not the number of loaders, we conclude that two loaders of the 25K type are optimal for all Coast Guard Air Stations. The substitution of another type of loader raises the considerations of reliability and speed of operation.

TABLE 3.4

Need for Loaders

Input:

C-130's 5 total, 1st with-4A rails installed and zero standby, next 4 without rails and one hour standby; -4 rails are used.

2 25 K loaders
6 salvage teams
3 HH 3's
2 E pkgs air delivered by C13Ø's
2 E pkgs air delivered by HH3's from HP1
0 E pkgs from HP2*
A manifold and HLD in each E pkg

Run Name	Distance to Scene Fm ECAS	Fm HP1	Bags Filled in 24 Hours	Number of Loadings	Number of Ldr Waits	Average Wait Minutes
NFA'	85	85	36	33	31	73
CBA	133	73	36	34	32	56
DBN	172	23	36	34	31	42
DBM	179	7	36	34	32	40
BAL	180	73	36	34	32	38
ACA	200	30	36	34	31	33
NYE	304	18	36	33	10	8
PMC	532	123	23	27	3	8
FSB	772	118	22	26	6	11

*This is also constraining, if two more E pkgs were used 40 bags could be filled e.g.

DBM1	179	7	40	25	not measured

Helicopters

The ADAPTS coverage is limited by the helicopter coverage available. If 24 hours is not a constraint, then small boats can be substituted for helicopters, but with this time limit the need for helicopters arises. As indicated in Chapter 1, the HH-52A is very limited in its ability to perform an ADAPTS mission. It can be used to carry four men to a scene within 100 miles radius of its air station and it can carry the weight of a third of a prepositioned equipment package out to 80 miles. In both cases it can stay at the scene for ten minutes and return with a half hour of reserve fuel when it arrives at its air station. The HH-3F on the other hand can deliver four men to a distance of 300 miles and a complete prepositioned equipment package roughly 170 miles and still spend ten minutes at the scene and have a half hour reserve fuel upon return to its air station. When either type of helicopter has work to perform at the scene, it must either travel a shorter distance than these limits or it must travel with no load. These distances are based upon the aircraft parameters given in Chapter 1 and on the assumption of good weather.

If the components of a prepositioned equipment package weigh the same as the prototype equipment package's components, then the HH-3F can deliver as follows with 30 minutes on scene time:

Component	weight in pounds	Distance
Pump	550 to 950	270 to 250
Engine	1150	230
Fuel	450	280

However, these distances [illegible] penalty of time lost [illegible] complete pump is delivered; therefore, this is feasible only when there are

two or more HH-3F's. This aspect was not investigated further.

The work that a helicopter may be required to do at the scene includes:

- delivery and evacuation of men
- delivery and evacuation of equipment
- retrieval of the HLD
- retrieval of messengers from C-130 dropped packages
- towing of anchored packages, and
- lifting of packages or their components from the water.

The advantages of helicopter towing of packages are:

- time saved and
- the strenuous work requirements for the salvage team are reduced.

The great disadvantage is the safety factor. Roughly 15 minutes can be save per package towed when compared to a package hauled manually with the HLD (assuming hauling 100 yards, it is more for the [illegible]). This time savings is minor when compared to the safety factor and, since it is not always accumulative (see Table 3.5 for example, in it run [illegible] shows a 24 minute improvement after 20 bags), there is little to be gained from risking the tow of a package through the water unless a rapid acting and reliable safety release is available. The other advantage of helicopter towing in reducing the strenuous work of the salvage team can be met by having a power takeoff from the Diesel or the lighting and communications set.

The idea of having the helicopter lift loads out of the water and place them on deck of a distressed ship has merit. It can do this safely in comparison to towing and, including hook-up and release [illegible], [illegible] is [illegible] is much shorter in duration that the [illegible] of delivering [illegible], [illegible],

TABLE 3.5

Pert Diagram Runs for Delaware Bay Entrance

RESOURCES @ ECAS
1 C130 immediately
2 C130 w/o rails on 1 hr. stdby
2 C130 loaders (not 25K loaders
8 man salvage team
2 E pkgs

3 HH52 @ CMAS*

3P9 Normal run
TOW = 3P9 with helo towing
MFD = 3P9 with manifolds
BET = 3P9 with helo towing and manifolds

Bag	TIME FILLED 3P9	TOW	MFD	BET	Time Saved 3P9 Compared to BET
1	408	380	408	380	28
2	581	533	581	533	28
3	699	671	699	671	28
4	725	697	702	674	51
5	843	815	820	792	51
6	869	841	823	795	74
7	987	959	941	913	74
8	1013	985	944	916	97
9	1131	1103	1062	1034	97
10	1157	1129	1065	1037	120
11	1275	1247	1183	1155	120
12	1301	1273	1186	1158	143
13	1419	1391	1304	1276	143
14	1445	1417	1307	1279	166
15	1563	1535	1425	1397	166
16	1589	1561	1428	1400	189
17	1707	1679	1546	1518	189
18	1733	1705	1549	1521	212
19	1851	1823	1667	1639	212
20	1877	1849	1670	1645	235
Final Dif.	(0)	(28)	(207)	(235)	

*Only 1 helo is necessary at this location; in order to save debugging time, 3 helicopters were used in the computer program.

TABLE 3.6

LIFTING EQUIPMENT BY HELICOPTER AT SCENE

EQUIPMENT	WEIGHT
PUMP PACKAGE	4,800 #
PUMP	455 #
ENGINE	1,150 #
FUEL	450 #
BAG PACKAGE	12,500 #
BAG	8,500 #

HELICOPTER LIFTING CAPACITY AT SCENE (MAXIMUM POUNDS)

TYPE	50 MILES	100 MILES	150 MILES	200 MILES
HH3	5770	5340	4900	4450
HH52A	1400	855	--	--

THE ABOVE ALLOWS FOR ONE CREWMAN MORE THAN MINIMUM.

*SAMPLE COMPUTATION, HH-3F HAS 7000# LIFT CAPACITY

(150 MILES) (1100#FUEL/HR)/(125 MPH RETURN SPEED)

= 1320 # FUEL NEEDED TO RETURN TO AIR STATION

+600 # FUEL 1/2 HR RESERVE

+180 # CREW MEMBER

= 2100 # LIFT CAPACITY USED UP

7000 - 2100 = 4900 #

and lifting which requires up to an hour. Table 3.6 shows that the individual components of an equipment package can be lifted by helicopters at scenes as distant as 50 miles for an HH-52A and 200 miles for an HH-3F if they have no excess weight of fuel on board and assuming good weather. This indicates that an effort to develop a safe method of connecting a hovering helicopter to a load in the water is desireable.

Equipment Packages

Every equipment package that is delivered by a C-130 takes the place of a bag package that could have been delivered. Rarely will the number of C-130's available be sufficient to allow having all equipment packages delivered by C-130. The other extreme is the situation in which the C-130's deliver no equipment packages and all are delivered by helicopter. This situation is limited by the helicopter coverage. A balance is desired between these extremes. Compare the results of computer runs DBM and DBM1 given in Table 3.4. Run DBM shows that even with the best available number of C-130's, the desired output of 40 bags in 24 hours can not be attained with four equipment packages while run DBM1 shows that it can be attained with six equipment packages. Table 3.7 provides more comparisons. The data in Table 3.7 also includes information on the waiting of bags that are ready for filling but which can not be filled until a pump is available. This data on waits is measured at the time 10 bags (40 bags for runs NYB, NYE, NYI, DBM, and 5P1) are filled and not at the end of 24 hours. In some instances when C-130's are not delayed but the bags are delayed, the time to fill 40 bags becomes long. As a result many more C-130 trips can

TABLE 3.7

THE EFFECT OF ADDITIONAL PUMPS

RUN	HP1	HP2	EQUIPMENT FM HP1	EQUIPMENT FM HP2	PKGS FM ECAS	NUMBER of C-130's	BAGS Filled in 24 Hours	WAITS FOR EQUIP No.	WAITS FOR PKG* Average Time
NYB	BAS	CCAS	2	2	2	5	44	45	16
NYE	BAS	-	2	-	2	5	36	54	135
NYI	BAS	CMAS	2	2	2	5	44	45	14
ACO	CMA	ECAS	2	0	2	5	36	68	236
ACQ	CMAS	ECAS	2	2	4	5	55	48	21
2PL	CMAS	-	0	-	2	2	13	7	49
AAE	CMAS	-	0	-	3	2	15	7	38
2LP	CMAS	-	0	-	2	2	13	8	66
BBF	CMAS	-	0	-	3	2	16	7	52
BET	CMAS	-	0	-	2	3	16	16	135
DA2	CMAS	BAS	1	1	1	3	25	1	9
DBM	CMAS	-	2	-	2	5	36	57	160
5P1	CMAS	-	5	-	2	5	40	46	14

*See discussion.

be made in the lengthened time and the model allows the delivery of more bags which increases the number of bags waiting and the length of wait disproportionally. For this reason, the data on the waits for equipment packages is presented only to indicate the relative improvements achievable; In an actual deployment of ADAPTS, the salvage teams would see the line of waiting bags and they would request more pumps. Runs DBM and 5P1 are included since they also differ in the type of rails used on the C-130's. Run DBM uses -4A rails while the other uses -4 rails, note that the -4A rails allow more bags to be delivered but that they can not be used since there are only four pumps. Also note that in run 5P1 the 5 pumps delivered by helicopter from HP1 (the nearest air station operating helicopters) are not as effective as desired since their delivery is spread over nine hours. (One of the C-130 delivered pumps was delivered later yet.). This implies that all five pumps prepositioned at air stations for helicopter delivery will not be effective. The other runs show that two pumps per air station for helicopter delivery are effective.

This discussion has been limited to prepositioning equipment packages (pumps) at Coast Guard Air Stations for delivery by helicopter. The optimal number of packages appears to be two or three but, for the reasons cited earlier, without being able to predict the probable size and location of oil spills, we can not determine whether the cost of a third package at Air Station is justifiable. The advantages of this form of prepositioning are the rapid delivery from a closer air station and the releasing of the C-130 space for additional bag delivery. Should the Coast Guard procure air cushion vessels, they would yield the same advantages and also may plug some of the holes in the heli[illegible] coverage.

Equipment packages could also be prepositioned at sites of high pollution probability (when they are known) to further reduce deployment time and problems.

Other System Improvements

The improvements of the C-130 loading process and the addition of prepositioned equipment packages are the major system improvements addressed by this study; they are intended to increase the speed of deployment to the scene and include:

- use of the more expensive -4A rails in lieu of -[illegible] rails so that C-130's become available quicker,
- use of 25K loaders in lieu of flat beds to increase the turnaround rate for C-130's,
- using HH-3F's to lift heavy loads at the scene, and
- delivery of prepositioned equipment by HH-3F.

Other system improvements are desireable to decrease the time required to perform tasks at the scene and to make the system more versatile. These include:

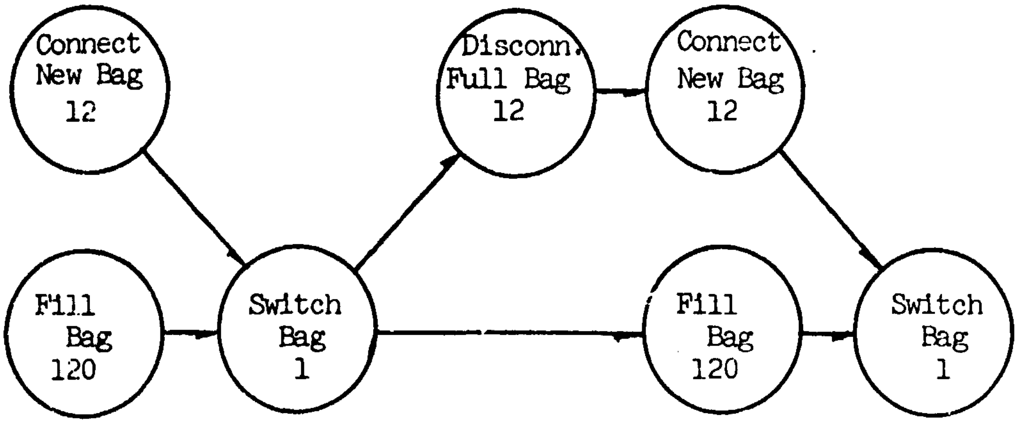
- the development of a hose package,
- the inclusion of a manifold in the equipment package, and
- the inclusion of a power winch on the HLB (A-frame).

The development of a hose package will allow direct pumping from one tanker to another (or a tank barge) which is anchored at a safe distance from the stricken vessel. It will also allow transference of oil to trucks ashore or even to tanks ashore when the stricken vessel is [illegible] beach or in a harbor. Lastly it will [illegible] [illegible] to the barrier system.

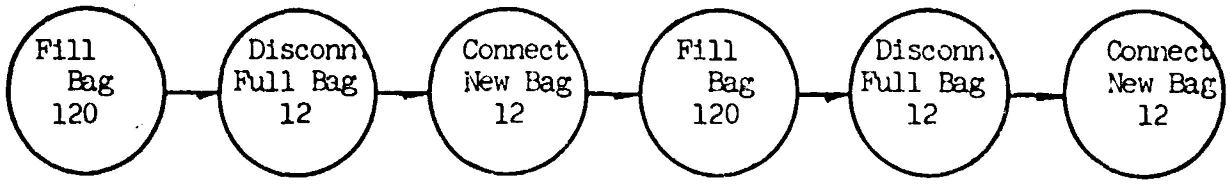
The inclusion of a manifold in the equipment package will allow the switching of oil flow from a full bag to an empty bag without stopping the pump. The manifold can be as simple as a Y-gate. With the manifold a pump can fill a bag every two hours, while without the manifold, the pump is idle for roughly 12 minutes while the full bag is disconnected from the pump and idle for another 12 minutes while an empty bag is connected; therefore, without a manifold a pump can fill a bag every 2 1/2 hours and it is not filling 17 percent of the time. Figure 3.9 is a simple network representation of this, the number in each activity circle is the duration of the task in minutes and the arrows indicate precedence. Note that a pump which is delivered and set up by the end of four hours can fill ten bags before 24 hours are up if it is equipped with a manifold and it can fill 8 bags without. Table 3.5 gives a direct comparison between the use of manifolds (run MFD) and the lack of them (run 3P9). Although - 4 rails and makeshift loaders are used in those runs in lieu of the faster equipment, thus constraining unnecessarily the number of bags at the scene, an improvement of two bags filled in 24 hours is achieved by using manifolds. If the maximum amount of resources at San Francisco Air Station are used with manifolds included, 36 bags can be filled at best only 37 miles from the Air Station. Without manifolds the results drop to 31 bags in 24 hours (runs SFB and SFB1 respectively).

The inclusion of a power winch on the HLD in addition to the manual winch would improve hauling time and reduce the manual labor at the scene. The power for the winch could be supplied from the Diesel engine of an equipment package (in this case the hauling must be done manually until the

MANIFOLD TIME SAVINGS



A. With a manifold a bag requires 121 minutes of a pump's time.



B. Without a manifold a bag requires 144 minutes of a pump's time of which 120 minutes are actually used in pumping.

Figure 3.9

first pump is set up) or from the power supply of the lighting and communications set. In either case it can simply be a hand held AC/DC electric drill with a chuck adapter to drive the currently installed manual winch. The advantages of having a power winch are that fewer men are required to winch in the load so the other men are free for other work or for rest and that the hauling time can be reduced. The disadvantages are that it is not useable until the power source is set up and that, if care is not used, the messenger line could be broken by a snag.

The power winch and the hose packages are not considered to be as important as improvements as manifolds and the aircraft improvements. They are not crucial to the optimal operation of ADAPTS for its design mission while the other improvements are; their development can be assigned to the salvage detail on a "not to interfere with training" basis.

Realistic Quantities of Resources

The preceding analyses of the incremental benefits attainable through the use of additional units of a given resource were done by having a more than optimal amount of the other resources in the computer runs to reduce their restraining effects. In the case of the air crews, for example, five C-130's were assumed for all data points in the generation of table 3.2 although the probability of having five C-130's at any time is [illegible] on the East Coast and zero elsewhere. A more realistic and conservative approach would be to use the average figure of three C-130's for the East Coast. Figure 3.1[illegible] illustrates the filling rates that can be expected with three C-130's ([illegible] average number available), three HH-3F (coverage available [illegible] on roughly half of the East Coast), two 25% loaders (the recommended type and [illegible]) for the C-130's ([illegible]), five air c[illegible]

PRACTICAL FILLING RATES FOR

VARIOUS AIRCREW ENDURANCES

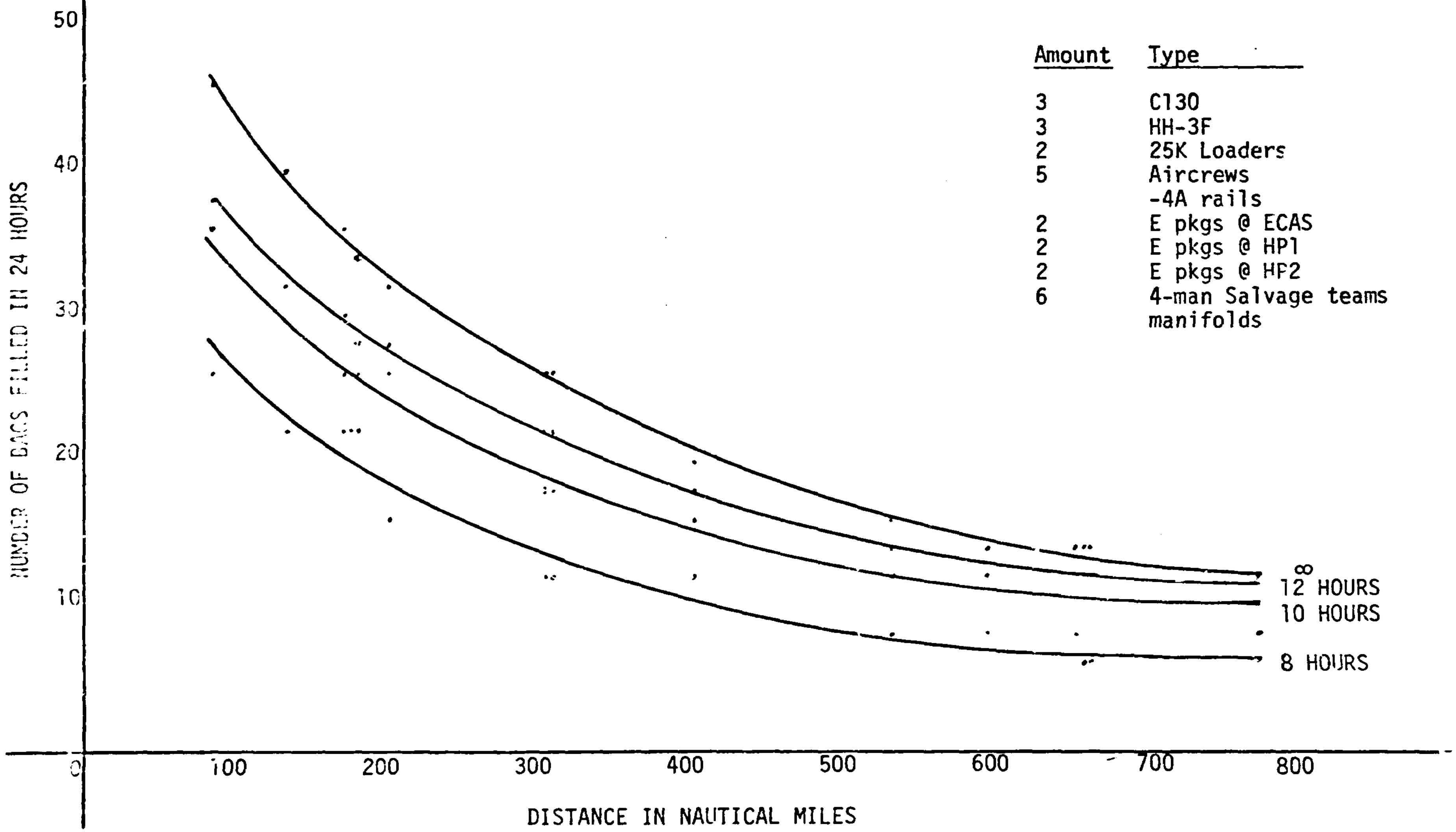


Figure 3.10

for the C-130's (currently available at Elizabeth City Air Station, six four-man salvage teams (24 men in total to deliver to the scene), six equipment packages (two each from Elizabeth City, the air station nearest to the scene, and the next nearest air station), and a manifold and HLD in each equipment package. Four curves are given in figure 3.10. The one for 8 hours flight time allowed per aircrew (see paragraph 202.2.1 of the Air Operations Manual, CG-333) is the most likely curve while the one for unlimited hours is the least likely. The 10 and 12 hour curves are possible depending upon administrative decisions concerning the nature of the ADAPTS mission (it is not SAR, can it be considered logistic?). Note that since there will be at least three C-130's available at Elizabeth City Air Station 90% of the time, these curves give the lower bound; that is, for 90% of the time the results of a deployment will be equal to or better than the results given on these curves. Table 3.2 on the other hand presents the upper bounds. For both figure 3.10 and table 3.2, the results are dependent upon having good weather, HH-3F's, etc.

A comparison of the results given in Table 3.2 with the results in figure 3.10 shows that three C-130's with five aircrews are superior to five C-130's with five aircrews when crew endurance is 8 or 10 hours and they are equivalent when crew endurance is 12 hours.

In terms of the average spill of 15,000 tons (30 bags) at 300 miles from Elizabeth City, three C-130's are insufficient while five C-130's are adequate only if eight or more flight crews are available with endurances over ten hours.

On the West Coast, where there are only two C-130's stationed at San

Francisco Air Station, the two C-130's can be expected to be available roughly half of the time.

This means that for a spill:

Spill at	Number bags
San Francisco	24
Los Angeles	10
Puget Sound	6
Strait of Juan de Fuca	6

is the best that can be done in 24 hours even if there are three aircrews available for ten hours each.

As can be seen from the above, the early deployment of ADAPTS is critical; this means that at least one C-130 must be ready (with -4A rails installed) for loading at a moments notice and that the others must be ready for rail installation within an hour and for takeoff within three hours of notification. These are the time constraints used during this study; any slippage reduces the number of bags delivered and filled within the 24 hour constraint.

Summary

This study did not consider the cost effectiveness of purchasing additional C-130's for purposes of attaining the desired goal of 40 bags delivered and filled anywhere along the U. S. coasts. As stated early in this report, cost effectiveness can not be measured since the need for ADAPTS can not be described adequately in terms of probable oil spills. However, figure 3.6 does present the best possible result curves for various distances and amounts

of C-130's (up to 15) at a single air stations; note that these curves results from assuming three HH-3F's available within roughly a 150 miles distance of the scene. Table 3.2 illustrates the results that can be expected if all C-130's at Elizabeth City are available while figure 3.1[illegible] illustrates the results that can be met or exceeded 50% of the time. Both are based on the assumption of good weather—weather that does not interfere with the air and surface tasks of [illegible].

From Table 3.2 and figure 3.1[illegible], it can be concluded that with five or less C-130's, two extra aircrews and a crew endurance of 12 hours is nearly as good as having unlimited use of the C-130's for 24 hours (after initial standby). Also the changing of crew endurance from eight hours to twelve hours is equivalent to having two more aircrews at eight hour endurance. This equivalency is [illegible] upon considering the [illegible] deployment as a multisortie [illegible] mission and open [illegible] weather.

CHAPTER 4

CONCLUSION

Unresolved Questions

As is often the case, this study was not able to answer all the questions that arose. Some of the questions are given in the preceeding chapters as they arise.

1. What is the probable size and location of an oil spill?

2. ADAPTS generates a need for additional C-130's at San Francisco. How many can ADAPTS justify?

3. ADAPTS generates a need for C-130's stationed on the Gulf Coast. How many, where should they be placed for best coverage of area of high spill probability?

4. What are the optimal number of bags to purchase and the optimal inventory policy for bags?

5. Would cargo carrying air cushion vehicles (10 to 20 ton capacity) be feasible for delivering the ADAPTS equipment packages, personnel, and bag packages? If so would they replace or supplement the C-130 and helicopter delivery methods?

6. If air cushion vehicles are feasible, are they quick enough for the 24 hour constraint? How many to buy and where to station? Cost effective? Other missions such as ATON or dedicated resource?

7. Should tankers (tank barges) of opportunity be used in conjunction with hose packages to supplement the C-130 delivery of bag packages?

8. Should a smaller bag be developed for prepositioning and delivery by HH-3F?

9. Should more HH-3F's be purchased to improve ADAPTS coverage around Cape Lookout and Cape Hatteras?

10. Is there a season during which the danger of a spill is greater? If so, is an increased readiness posture desireable?

The first question is the key that opens the door to answering the others.

Recommendations

1. That planning to purchase and deploy ADAPTS be based initially upon the average spill of 15,000 tons at a distance of 360 miles from Elizabeth City Air Station. This will provide coverage for the East Coast under most circumstances. This recommendation should be reevaluated once recommendation three is accomplished.

2. That the positioning of ADAPTS on the West Coast be delayed until the need for ADAPTS be identified for that coast; see recommendation three. The lack of sufficient C-130's (only two at San Francisco) and the lack of HH-3F helicopters (only at San Diego) render adequate response for a large spill impossible to any location beyond the approaches to San Francisco; there the best possible results are half of the Specific Operational Requirement.[1]

3. That the probability of an oil spill be determined along with the probable size and location of the spill. This is necessary in order to

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[1] See [illegible] of 8 April 1971

determine the number of aircraft and ADAPTS packages. Any advanced siting of ADAPTS is dependent upon knowledge of this.

4. That a cost benefit analysis of the alternative methods of delivering equipment packages be determined AFTER experience in deploying ADAPTS has been gained and AFTER the probable size and location of oil spills can be predicted.

5. That -4A rails be purchased and that all Coast Guard owned C-130's be modified to use them. The conversion of the entire fleet on one or two contracts will result in large dollar savings and will allow relocation of aircraft from one station to another as needed.

6. That a simple manifold such as a Y-gate be installed on each equipment package to direct the output of the submersible pump to one or two bags and to allow switching bags without stopping the filling of bags.

7. That two loaders equal in capacity, speed of operation, and safety be purchased for each C-130 equipped air station. This may be done slowly as the ADAPTS packages are positioned at the air stations or it may be done in conjunction with the purchase of the -4A rails so that the advantages of the rail system can be realized for logistic flights.

8. That each air station have two equipment packages ready for helicopter delivery and that the C-130 equipped air stations have four air droppable equipment packages.

The seventh and eighth recommendations are made with the assumption that at least a capacity of delivering ADAPTS pumps is needed for each C-130 equipped air station. This presupposes that the results of recommendation three will indicate some need for ADAPTS on each coast. This study has

found that an average large spill of 15,000 tons occurs on the East Coast. That a problem does exist on the West Coast and the Gulf Coast is obvious after the collision of two tanker in San Francisco and the grounding of a tanker at San Juan, P. R.

ERRATA

Volume 1

Page 5- First line, sub para (a)
Change the word "equipment to "equipped".

Page 17- Line one
Delete the words, "the use on".

Page 37- Line three
Change "600 to "500".

Page 49- Last line
Correct the first word to read, "interface".

Volume 2

Page 25- Last line
Correct to read, "more than one helo at a time with E pkgs".

Page 28- Fourth from bottom line
Change the word between "to" and "painted" to read "[illegible] be".

Page 29- Last line, first paragraph
Add an asterisk (*).

Bottom of the page- add the following:

* The model will not produce a "best" deployment, only a comparison of possible deployments under varying circumstances.

Line seven, second paragraph
Beginning of the sentence should read, "any or all of them".

Volume 3

Page 4- Last line, first paragraph
Add an asterisk (*).

Bottom of the page- add the following:

* C130 cannot land at BAS. This reloading of equipment would have to be accomplished at a nearby commercial airfield.